Case No. 10599/10
e-tenna ref. 11

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)	
William E. McKinzie, III, et al.	)	
Serial No. 09/845,666	)	Examiner: Le, Hoanganh
Filing Date: April 30, 2001	)	Group Art Unit No. 2821
For RECONFIGURABLE ARTIFICIAL MAGNETIC CONDUCTOR	)	

DECLARATION UNDER 37 C.F.R. §1.131

Commissioner for Patents
Washington, D.C. 20231

Dear Sir:

The undersigned, WILLIAM E. MCKINZIE, III, VICTOR C. SANCHEZ, MARK REED AND STEVEN L. GARRETT, hereby declare that:

1. We are the applicants of above-identified patent application and co-inventors of the subject matter described and claimed therein.

2. Prior to March 29, 2000, the invention as described and claimed in Claims 1 and 2 of the subject application was made in the U.S. as evidenced by the following:

3. Attached as Exhibit A is a relevant portion of a proposal created prior to March 29, 2000 (dates have been redacted in the attached) setting forth various aspects of our invention, including an artificial magnetic conductor (AMC) featuring a

frequency selective surface (FSS) having an effective sheet capacitance which is variable to control resonant frequency of the AMC. The proposal document is entitled ARCHES: Antennas in Reconfigurable High Impedance Electromagnetic Surfaces ("ARCHES Proposal").

4. As shown in Exhibit A at, for example, page 16, section H.1, the concept of an artificial magnetic conductor is described. Figure H-1(a) shows "an example of an UHF (350 MHz) artificial magnetic conductor," which has a capacitive frequency selective surface (FSS) including a single layer of conductive patches disposed on a dielectric layer.

5. Exhibit A also describes concepts for a reconfigurable AMC, for example, at page 20, section H.1.2. The second paragraph of section H.1.2 states

> Two basic approaches are identified for AMC reconfigurability: 1) Modify the FSS effective sheet capacitance, which can be done discretely with PIN diode switches or continuously with varactor diodes....

The fourth paragraph of section H.1.2 states in reference to Figures H-8, page 21:

> The basic concept in Figure H-8 is to reconfigure the effective sheet capacitance of an FSS by using PIN diode switches. Surface mounted diodes are used to change the size of overlapping printed patches. The OFF state capacitance of the diodes is lumped with or absorbed into the parasitic capacitance between FSS patches. So no resonating inductors are required to maintain a high open circuit impedance. The vias, indigenous to the high-impedance surface, are used to route bias currents and voltages from stripline control lines buried inside the RF backplane..... We predict the range of effective capacitance to be about 25:1, which would yield a 5:1 ratio of reconfigurable AMC center frequency,

6. The ARCHES proposal also details embodiments of hardware for use in our invention, for example in Figures H-8, H-9 and H-10, pages 21-22. Figure H-8 shows the physical relationship between conductive patches of the FSS, the vias through the FSS, the RF backplane and the PIN diode switches for varying the effective

sheet capacitance of the FSS. Figure H-9 shows a PIN diode control circuit. Figure H-10 shows the FSS in conjunction with varactor diodes for varying the effective sheet capacitance of the FSS.

7. Exhibit B includes slides from a presentation for a Technological Interchange Meeting, referred to as TIM-2. TIM-2 was held April 10, 2000 to discuss the previous six months' developments under the ARCHES Proposal. Specifically, Exhibit B shows the "Executive Summary" of the TIM-2 meeting.

8. Slide I-2 of Exhibit B identifies the basic approach under the ARCHES Proposal. Phase I involved "Creat[ing] an electrically-thin Artificial Magnetic Conductor (AMC)." Phase II involved "Fabricat[ing] wire antenna elements in close proximity to the AMC." Phase III involved "Electronically reconfigure[ing] both the element resonant frequency."

9. Slide I-6 of Exhibit B illustrates tasks to be completed under the ARCHES proposal. Task 1.0 is "Integrated Ground Plane (IGP) Technology Dev[elopment]: Conduct research and technology development needed to realize broadband and/or reconfigurable artificial magnetic conductors (AMCs) with embedded radiating elements."

Task 1.0 includes four sub-tasks:

(a) Task 1.1 is "Passive Broadband AMC Dev[elopment]: Design, model, fabricate, and test hardware concepts for increasing the bandgap of AMCs. Both circuit and material approaches will be used. The goal is a 2:1 bandgap in the 0.2-2.0 GHz band."

(b) Task 1.2 is Reconfigurable Bandgap AMC Dev[elopment]: The basic goal is to realize a frequency tunable AMC, where the bandgap may be electronically reconfigured by controlling the reactive nature of the high-impedance surface using arrays of solid state devices. The goal is to reconfigure the bandgap to cover 0.2-2.0 GHz."

10. Thus, development of the reconfigurable AMC, including a frequency selective surface (FSS) having an effective sheet capacitance which is variable to control resonant frequency of the AMC, was one task of the overall ARCHES Proposal. Development of the reconfigurable AMC as Task 1.2 depended on and chronologically followed development of the passive broadband AMC as Task 1.1. Work in pursuit of Task 1.1 was necessarily a precursor and part of work in pursuit of Task 1.2.

11. This is further demonstrated by slide I-14 of Exhibit B. This slide shows a schedule, milestones and costs for work under the ARCHES Proposal. According to this schedule, preliminary work in development of a passive broadband was set to occur in preparation for development of the reconfigurable bandgap AMC.

12. This is still further demonstrated by slide I-7 of Exhibit B. This slide of the Executive Summary describes at a high level "what's new and original with the ARCHES Program?" The "first 6 month's effort" is boxed and highlighted in green. The focus of the development work during this initial part of the program was "Techniques to increase the bandwidth of the Sievenpiper AMC concept," and "Concepts for effective media electromagnetic modeling of AMCs which may facilitate rapid design and analysis of AMC integrated antennas.

13. Thus, as of April 10, 2000, preliminary work had been completed toward development of a reconfigurable AMC with a variable effective sheet capacitance was under way.

14. Exhibit C is a Monthly Progress Report on the ARCHES Program covering the period 1 May 2000 to 31 May 2000. This report was submitted to John Turtle of the Air Force Research Laboratory, Antenna Technology Branch. Section 4.0 "Technical Progress" defines progress during the reporting period on respective tasks under the ARCHES Program. The first paragraph of this section, Exhibit C, page 4, makes reference to the six-month technical interchange meeting, TIM-2, described in part above in connection with Exhibit B.

15. Figure 2 of Exhibit C illustrates scheduled work, budgeted costs and spending through the reporting period. To date, $15,501 had been spent on Task 1.2, reconfigurable bandgap AMC development, out of a budgeted $545,363. Also, at that time, for Task 1.1, passive broadband AMC development, $264,191 of a budgeted $325,981 had been spent.

16. Section 5.0, page 7 of Exhibit C describes plans for the next month, June 2000. Specifically, the planned work includes the following

> Also, we plan to finalize the design work associated with the reconfigurable AMC and begin the fabrication and test stage.

17. Thus, at this time, as evidenced by the Progress Report for the period from 1 May 2000 to 31 May 2000, design work on a reconfigurable AMC had progressed substantially and was nearing completion.

18. Exhibit D is a Monthly Progress Report on the ARCHES Program covering the period 1 June 2000 to 31 July 2000. This report was submitted to John Turtle of the Air Force Research Laboratory, Antenna Technology Branch. Section 4.0 of Exhibit D describes technical progress on the individual tasks during the reporting period. At page 9 of Exhibit D, technical progress on Task 1.2, Reconfigurable Bandgap AMC Development, is reported. The last paragraph of page 9 states

> Initial modeling was performed using a simple MathCad design tool. This model uses a lumped-element equivalent circuit model for the AMC structure and has previously provided good agreement with both more-detailed models and measurements. Following initial design runs, a more-detailed model (Flomerics' Microstripes Software) was used to refine the design.
>
> The design specifics and predicted reflection-phase performance of the AMC structure is shown in the figures below. The two reflection phase curves are for the extreme cases of the varactor diode bias state. Since the varactor capacitance tunes smoothly with bias voltage, the curve will tune in an analog fashion as bias voltage is applied between these two extreme states. The fabrication and test of this structure is ongoing and will be reported upon in subsequent briefings/reports.

19. Section 5.0, page 7 of Exhibit D describes plans for the next month, June 2000. Specifically, the planned work includes the following

> Also, some effort will be expended towards design and implementation of the reconfigurable AMC substrate.

20. Thus, at this time, as evidenced by the Progress Report for the period from 1 May 2000 to 31 May 2000, design work on a reconfigurable AMC had progressed substantially and was nearing completion.

21. Exhibit E is a Monthly Progress Report on the ARCHES Program covering the period 1 August 2000 to 30 September 2000. This report was submitted to John Turtle of the Air Force Research Laboratory, Antenna Technology Branch. Section 4.0 of Exhibit E describes technical progress on the individual tasks during the reporting period. At page 7 of Exhibit E, technical progress on Task 1.2, Reconfigurable Bandgap AMC Development, is reported. The last paragraph of page 7 states

> The purpose of this task is to analyze a reconfigurable AMC structure. The initial tuning mechanism to be investigated consists of varactor diodes placed across the patches of a single-layer the capacitive FSS to obtain variable capacitance, hence a variable tuning state for the AMC. *This portion of this task was completed during the reporting period, and led to the demonstration of a reconfigurable AMC* demonstration – discussed in task 3.1 below. The focus during this reporting period was on the varactor tuning method. However, there are other approaches to obtaining reconfigurable bandgaps (including pin diodes and other methods which tune the actual AMC substrate). We plan to investigate some of these methods in upcoming months. *(emphasis added)*

22. Pages 8 through 17 describe simulation and analysis of a varactor tunable AMC. Figure 4, page 8 of Exhibit E, illustrates a unit cell of the simulation. Figure 5, page 8 of Exhibit E, shows the equivalent circuit of the unit cell. Figures 8a and 8b, page 12 of Exhibit E, show simulated reflection phase coefficient, with resonances around 1.7 GHz and 0.53 GHz, respectively. Figure 9, page 12 of Exhibit E, shows simulated reflection phase coefficient with addition of tuning varactors, showing resonances around 1.54 GHz and 0.5 GHz, respectively. Figures 11 and 12, page 13 of

Exhibit E, show additional simulation results. Page 14 of Exhibit E, first paragraph, summarizes these results:

> With the present 3x3 design the selected varactors give a resonant frequency tunability range of 3:1, that is from 1.54 GHz to 0.511 GHz, with associated operational bandwidths of 11.3% and 3.08% respectively..... The lesson is that series inductance added to the FSS can increase the tunability of varactor tuned AMCs by bringing down in frequency the LC resonance of the FSS layer. This causes a frequency dependent increase in apparent capacitance over the operational band that allows us to get lower frequency resonances but at the same time narrows the operational bandwidth.

Pages 14 through 17 of Exhibit E show additional simulation results related to surface wave behavior of a varactor tunable AMC.

23. Pages 18 through 21 of Exhibit E show the results of Task 3.1, demonstration of a narrow-instantaneous-band reconfigurable bandgap AMC. Figure 14, page 19 of Exhibit E, shows the design specifics of a realized AMC structure. Figure 14 specifies in detail the geometrical orientations and measurements, material and devices used in this example, including the specific model of varactor chosen, model MA46H202 manufactured by M/A-Com. A range of varactor capacitance values Cv are specified, from 0.6 pF to 7 pF. Figure 15 shows <u>measured</u> reflection phase for the reconfigurable AMC described in Figure 14 for various bias states. Figure 16 shows <u>measured</u> surface wave performance for the reconfigurable AMC described in Figure 14. In Figure 15, as bias state is varied and the capacitance Cv varies, the reflection phase of the AMC varies. In Figure 16, as the bias state is changed the surface wave bandgap for TE and TM mode waves varies as well, evidencing the variation in effective sheet capacitance.

24. These results are summarized at page 21 of Exhibit E:

> The results are consistent with predictions and indicate that a varactor-tuned AMC surface is feasible. A high impedance and surface wave bandgap were demonstrated to tune over approximately a 3:1 tuning range (650 – 2100 MHz).

25. Thus, by at least 30 September 2000, we had demonstrated an artificial magnetic conductor (AMC) which included a frequency selective surface having an effective sheet capacitance which is variable to control resonant frequency of the AMC.

All statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true, and further these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful statements may jeopardize the validity of the application or any patent issuing therefrom.

Respectfully submitted,

William E. McKinzie III — 2/24/03

WILLIAM E. MCKINZIE III — Date

VICTOR C. SANCHEZ — Date

MARK REED — Date

STEVEN L. GARRETT — Date

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VICTOR C. SANCHEZ	2/24/03 Date
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VICTOR C. SANCHEZ	Date
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WILLIAM E. MCKINZIE III	Date
VICTOR C. SANCHEZ	Date
MARK REED	Date
Steven L. Garrett	25 Feb 03
STEVEN L. GARRETT	Date